ProstateSBRT-ARTIA-SIB40-36Gy Model Description

Purpose:

This document describes the context in which the ProstateSBRT-ARTIA-SIB40-36Gy model should be used, as well as how it was configured and validated. All instruction needed to use this model in your clinic can be found when you **read the first 14 pages of this document**.

Applicability:

Note *RapidPlan knowledge-based planning and its models are not intended to replace clinical decisions, provide medical advice or endorse any particular radiation plan or treatment procedure. The patients' medical professionals are solely responsible for and must rely on their professional clinical judgment when deciding how to plan and provide radiation therapy.*

Note *The performance of ProstateSBRT-ARTIA-SIB40-36Gy may vary depending on the contouring and planning guidelines. Each site should validate the model with institution-specific contouring and planning guidelines before clinical use.*

Note *You should validate every DVH estimation model before using it clinically. This applies to any model, whether Varian provided, peer provided or the models you create yourself.*

- ProstateSBRT-ARTIA-SIB40-36Gy was designed per the Adaptive Radiation Therapy Individualized Approach - Prostate (ARTIA) trial that includes aggressive margins and urethral sparing where the urethral dose at 0.1CC should be <35Gy. However, ProstateSBRT-ARTIA has demonstrated the ability to make high quality plans with larger margins, without urethral sparing by omitting urethral specific structures (See Annex C), or by scaling the dose to the Urethra differing from the original ARTIA intent (See Annex D).
- ProstateSBRT-ARTIA is intended to be used for RapidArc treatment plans of 6 full arcs on Halcyon/Ethos or 3 arcs on TrueBeam (See Annex A).
- ProstateSBRT-ARTIA supports two major targets: 40Gy and 36.25Gy treated Simultaneous Integrated Boost. However, when using this model up to four dose levels can be specified: CTV-UrethraPRV=40Gy; PTV-UrethraPRV=36.25Gy; PTV+Rectum=34.44Gy (If exists); PTV+Urethra=33Gy (default, other values accepted).
- An associated 32 metric dosimetric scorecard can be used to evaluate plan quality and automatically generate the optimization structures needed (see page 6 for details or manual creation)
- For best results, it is recommended to use AcurosXB dose calculation with a resolution size of 0.125cm
- The "**Automatic Intermediate Dose**" function of the Photon Optimizer was utilized with **MR3** return and **convergence mode: extended** selected in the calculation options which provide best results. These **settings should be changed prior to starting the optimization or plan quality will be compromised.** For increased homogeneity, **consider an additional intermediate dose optimization: "2xMR3".**
- For Eclipse V18.0 Halcyon/Ethos planning only: consider using previous Photon Optimizer (i.e. V16.1/V17), but for most accurate final dose calculation use latest version of AcurosXB (See Annex A4).
- ProstateSBRT-ARTIA was created using the guidelines described below.

Example of patient eligibility from the ARTIA-Prostate trial

1. Patient has NCCN low or intermediate risk prostate cancer that is biopsy proven.

NCCN Risk Group	Clinical/Pathologic Features		
Very Low	Has all of the following: cT1c Grade Group 1 PSA < 10 ng/mL Fewer than 3 prostate biopsy fragments/cores positive, ≤ 50% cancer in each fragment/core PSA density < 0.15 ng/mL/g		
Low	Has all of the following but does not qualify for very low risk: cT1-cT2a Grade Group 1 PSA < 10 ng/mL		
Intermediate	Has no high-risk or very-high-risk group features one or more intermediate risk factors (IRFs): cT2b-cT2c Grade Group 2 or 3 PSA 10-20 ng/mL	Favorable intermediate	Has all of the following: 1 IRF Grade Group 1 or 2 < 50% biopsy cores positive (eg, < 6 of 12 cores)
		Unfavorable intermediate	Has one or more of the following: 2 or 3 IRFs Grade Group 3 ≥ 50% biopsy cores positive (eg, ≥ 6 of 12 cores)

2. Prostate volume is ≤80cc as assessed by MRI or ultrasound prior to radiotherapy.
3. AUA/IPSS score is ≤ 15.
4. ECOG performance status is ≤2 (or Karnofsky score is ≥60%).
5. Patient has no PIRADS 4 or 5 lesion on prostate MRI contacting the urethra (determined at physician discretion).
6. Patient has the ability to complete required patient questionnaires.
7. Patient age ≥ 18 years (or greater than the local age of majority).
8. Patient has the ability to understand and the willingness to sign a written informed consent document.

Target contouring guidelines from the ARTIA-Prostate trial:

Standard Name	Description	Detailed Specification
CTV	Clinical target volume including prostate and proximal seminal vesicles Required	Includes the entire prostate and proximal 1cm of seminal vesicles as defined on the CT. The proximal 1cm is defined as the entire axial extent of the bilateral seminal vesicles that are 1cm superior to the takeoff of the seminal vesicles from the prostate. The seminal vesicles contour may be trimmed at the discretion of the treating physician, such as in cases where the seminal vesicles wrap around the rectum posteriorly. Using the fused MRI to assist with target delineation, care should be taken to exclude the bladder wall at the interface with the base of the prostate and to exclude the GU diaphragm/external urethral sphincter inferior to the prostatic apex.
CTV-UrethraPRV	Clinical target volume minus the (Urethra + 2mm margin) Required	This structure is automatically derived from the CTV and the Urethra (See Table 6). The derivation is a Boolean subtract of a 2mm expansion of the Urethra contour from the CTV.
PTV	Planning target volume Required	This structure is automatically derived. CTV + 0.3 cm uniform 3-dimensional expansion.
PTV-UrethraPRV	Planning target volume minus the (Urethra + 2mm margin) Required	This structure is automatically derived. The Urethra contour is expanded by 2 mm and this result is subtracted from the PTV.

Organ At Risk contouring guidelines from the ARTIA-Prostate trial:

Standard Name	Description	Detailed Specification
Body	External patient contour encompassing all patient anatomy with a single contour on each slice Required	The initial external body contour should be contoured on the simulation CT scan. For daily adaptive plans the Ethos system generates the external body contour on the synthetic CT.
Ring_PTV_2cm	All tissue in a 2 cm expansion from the PTV Optional (to facilitate the extent of sigmoid and bowel contouring)	All tissue within a 2 cm 3-dimensional expansion of the PTV. This optional tool can be used at physician discretion as a guide to visualize the superior extent of the bowel contours for adaptive planning. It is the intention that all bowel, bladder and rectum should be contoured within this sup-inf region.
Bowel_Small	Small bowel Required	All small bowel loops will be outlined on each axial CT slice and treated as solid structures
Bowel_Large	Large bowel Required	All large bowel loops including sigmoid will be outlined on each axial CT slice and these organs will be treated as solid structures.
Rectum	Rectum Required	The outer rectal wall will be contoured and the organ will be considered as a continuous solid structure, and will be defined from the level of the sigmoid flexure to the bottom of the ischial tuberosities.
Bladder	Bladder Required	The entire bladder should be contoured as a solid structure.

Femur_L	Left femur Required	The outer contours of the left femoral head will be delineated and filled in, treating each as a solid continuous structure. Do not include the femoral neck.
Femur_R	Right femur Required	The outer contours of the right femoral head will be delineated and filled in, treating each as a solid continuous structure. Do not include the femoral neck.
Fiducials or Fiducials+Spacer	Fiducial markers and Spacer contour Required (spacer optional)	The outline of all fiducials plus the hydrogel spacer (if present) are summed into a single structure. This structure needs to be of type "Markers" and needs to have a priority 2 goal set on it to be able to see it in all of the adaptive and imaging workspaces on the console (see constraints below). The Fiducials (including the rectal spacer, if present), the Urethra and the CTV will form a "constellation" of structures that are rigidly propagated to the daily adaptive plans and will maintain relative positions between each other
Urethra	Urethra Required	The entire intraprostatic urethra is contoured from the top of the penile bulb inferiorly up to and inclusive of the bladder neck superiorly. A sagittal T2 weighted MRI sequence should be fused to the planning CT for this purpose. A 4-6mm brush tool is typically used to delineate the structure. The superior portion of the urethral contour should be expanded to incorporate the bladder neck. The urethra must be defined 7-9 mm inferiorly below the inferior extent of the PTV to ensure adequate urethral sparing at the apex. This structure needs to be of type "Markers" to be part of the rigid propagation "constellation".

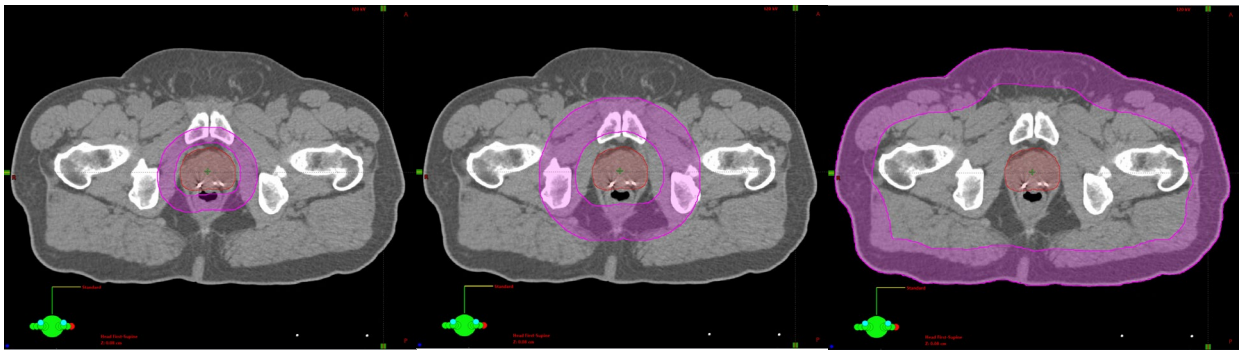
Optimization structure guidelines:

Model Structure	Derived Boolean/Expansion
PTV-UrethraPRV	“{<PTV> SUB <Urethra>|+2mm}” (Cropped from PTV+Rectum if present)
PTV+Rectum	“{<PTV> AND <Rectum>}”
PTV+Urethra*	“{<PTV> AND <Urethra>}” **(Use high resolution)**
CTV-UrethraPRV	"{<CTV> SUB <Urethra>|+2mm}“
PTV-CTV	“{<PTV> SUB <CTV>}”
PTV Ring	“{<PTV>|+20mm SUB <PTV>|+5mm}“
50per Ring	“{<PTV>|+50mm SUB <PTV>|+15mm}”
Body Ring	“{<BODY> SUB <BODY>|-35mm}”

*This model recommends PTV+Urethra as a union of the two structures (AND). However, the ARTIA Ethos Clinical Directive Template (CDT), generates PTV+Urethra as both (OR). See Annex E for use with the ARTIA CDT derived version of PTV+Urethra.

Note*: Optimization structures can be automatically created with ESAPI MAAS-PlanScoreCard tool or Ethos*

PTV Ring | 50per Ring | Body Ring



PTV with 2.0cm outer margin and cropped 0.5cm from PTV

PTV with 5.0cm outer margin and cropped 1.5cm from PTV

Body with 3.5cm inner margin

Treatment planning guidelines:

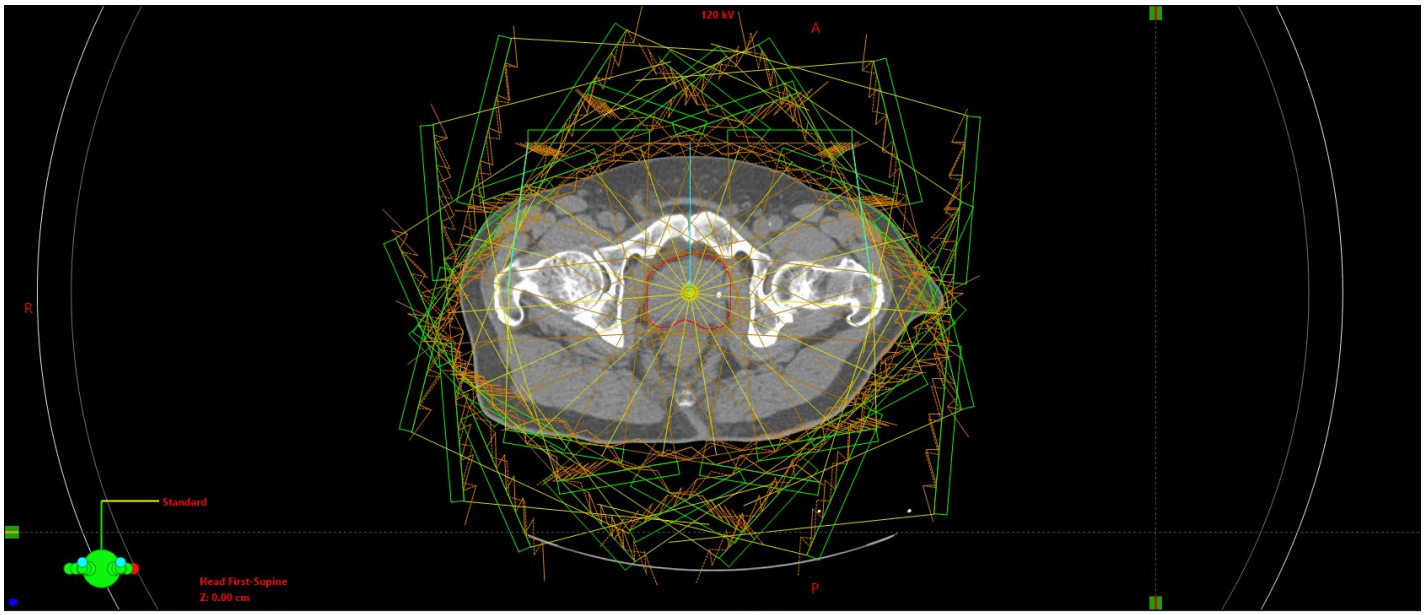
All cases used to train and to validate the model were planned using head-first supine position. All patients were immobilized with either an Alpha Cradle or Vac-Loc device. A six arc VMAT technique was utilized with full coplanar arcs on Halcyon with MLC in SX2 mode (standard mode on all Halcyon D / Drive and above configurations). Arcs had alternating clock-wise and counter clock-wise gantry rotations with collimator positions set at 300, 330, 0, 30, 60, and 90 degrees. The coplanar arcs had 360 degrees of arc rotation for each field. Arcs were positioned at a single isocenter located in the center of the PTV.

Fields | Dose | Field Alignments | Clinical Goals | Optimization Objectives | Dose Statistics | Reference Points | Calculation Models | Plan Sum

Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]
I	kVCBCT	Static-I	RDS3 Ti kV - 6X-FFF		0.000	IEC61217	0.0	0.0	0.00	0.00	0.00	87.6
I	CW	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	1.060	IEC61217	179.0 CCW 181.0	300.0	0.00	0.00	0.00	88.5
I	CCW	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	1.542	IEC61217	181.0 CW 179.0	330.0	0.00	0.00	0.00	88.5
I	CW1	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	1.984	IEC61217	179.0 CCW 181.0	0.0	0.00	0.00	0.00	88.5
I	CCW1	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	1.347	IEC61217	181.0 CW 179.0	30.0	0.00	0.00	0.00	88.5
I	CW2	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	0.989	IEC61217	179.0 CCW 181.0	60.0	0.00	0.00	0.00	88.5
I	CCW2	Arc Therapy-I	RDS3 Ti kV - 6X-FFF	VMAT	0.718	IEC61217	181.0 CW 179.0	90.0	0.00	0.00	0.00	88.5

Modify the isocenter group for 'CW1'

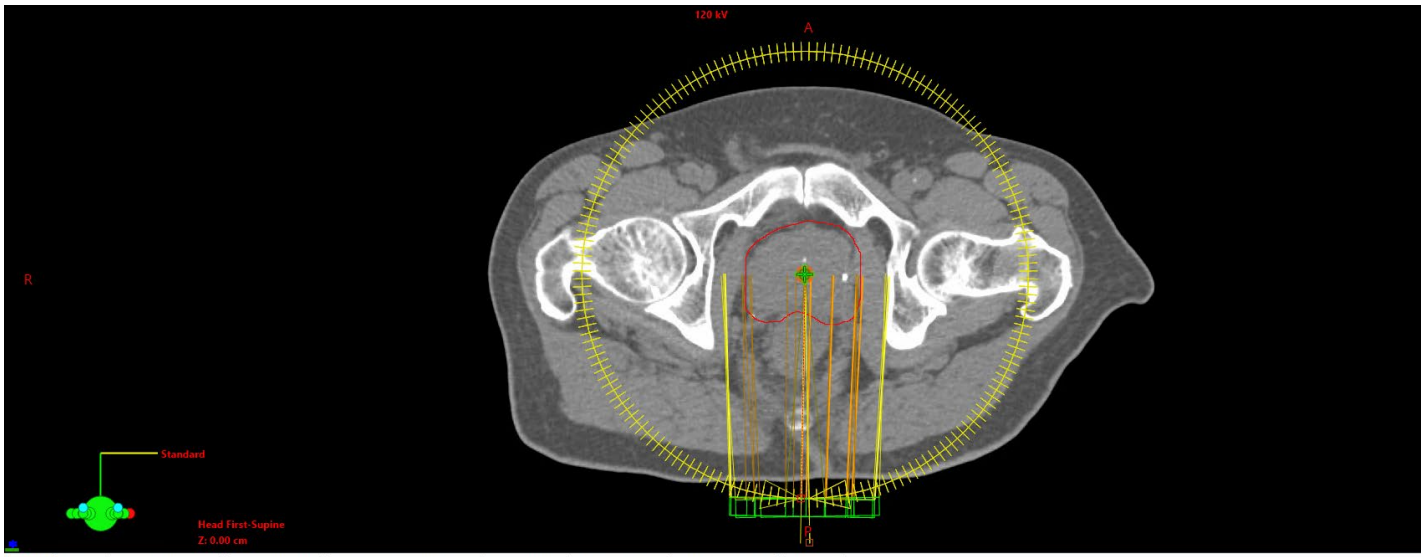
6 arc beam geometry used for model training and validation with Halcyon



Fields | Dose | Field Alignments | Clinical Goals | Optimization Objectives | Dose Statistics | Reference Points | Calculation Models | Plan Sum

Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]
I	kVCBCT	Static-I	RDS3 Ti kV - 6X-FFF		0.000	IEC61217	0.0	0.0	0.00	0.00	0.00	89.5
I	Field 1	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	189.5	270.0	0.00	0.00	0.00	88.4
I	Field 2	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	208.4	279.5	0.00	0.00	0.00	86.8
I	Field 3	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	227.4	289.0	0.00	0.00	0.00	84.0
I	Field 4	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	246.3	298.5	0.00	0.00	0.00	82.0
I	Field 5	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	265.3	308.0	0.00	0.00	0.00	82.4
I	Field 6	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	284.2	317.5	0.00	0.00	0.00	83.0
I	Field 7	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	303.2	327.0	0.00	0.00	0.00	85.9
I	Field 8	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	322.1	336.5	0.00	0.00	0.00	88.4
I	Field 9	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	341.1	346.0	0.00	0.00	0.00	89.2
I	Field 10	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	0.0	355.5	0.00	0.00	0.00	89.5
I	Field 11	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	19.0	5.0	0.00	0.00	0.00	89.2
I	Field 12	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	37.9	14.5	0.00	0.00	0.00	88.3
I	Field 13	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	56.9	24.0	0.00	0.00	0.00	86.2
I	Field 14	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	75.8	33.5	0.00	0.00	0.00	83.0
I	Field 15	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	94.8	43.0	0.00	0.00	0.00	81.0
I	Field 16	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	113.7	52.5	0.00	0.00	0.00	84.8
I	Field 17	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	132.7	62.0	0.00	0.00	0.00	85.6
I	Field 18	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	151.6	71.5	0.00	0.00	0.00	87.2
I	Field 19	Static-I	RDS3 Ti kV - 6X-FFF	Dose Dynamic	1.000	IEC61217	170.6	81.0	0.00	0.00	0.00	88.5

19-Field IMRT beam geometry used for additional Halcyon/Ethos validation



Fields | Dose | Field Alignments | Clinical Goals | Optimization Objectives | Dose Statistics | Reference Points | Calculation Models | Plan Sum

Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Rtn [deg]	Coll Rtn [deg]	Couch Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]
1	Field 1	Arc Therapy-I	SP_TrueBeam_Mill - 6X-FFF	VMAT	1.846	IEC61217	181.0 CW 179.0	350.0	0.0	None	9.0	-4.6	+4.4	7.5	-3.9	+3.6	0.00	0.00	0.00
1	Field 2	Arc Therapy-I	SP_TrueBeam_Mill - 6X-FFF	VMAT	2.176	IEC61217	179.0 CCW 181.0	10.0	0.0	None	9.0	-4.4	+4.6	7.5	-3.9	+3.6	0.00	0.00	0.00
1	Field 3	Arc Therapy-I	SP_TrueBeam_Mill - 6X-FFF	VMAT	1.496	IEC61217	181.0 CW 179.0	90.0	0.0	None	7.2	-3.8	+3.4	9.1	-4.6	+4.6	0.00	0.00	0.00

3 arc beam geometry used for TrueBeam validation

Target Clinical Goals

The following dose prescription and planning guidelines were used for the cases to train and validate the model.

Standard Target Name	Dose [Gy]	Fraction Size [Gy]	# of Fractions	Dose Specification Technique
CTV-UrethraPRV	40	8	5	>=98% of PTV should receive >=40 Gy
PTV-UrethraPRV	36.25	7.25	5	>=98% of PTV should receive >=36.25Gy
PTV+Rectum	34.44	6.9	5	>=95% of PTV should receive >=34.44Gy
PTV+Urethra	33	6.6	5	D0.5cc minimum of PTV+Urethra should receive >=31Gy

This model is compatible (trained and validated) with three or four dose levels, always: CTV-UrethraPRV, PTV-UrethraPRV, and PTV+Urethra. The PTV+Rectum is used when rectum is overlapping with the PTV (common when no spacer is used). For guidance scaling this model to different prescriptions see Annex F.

OAR Clinical Goals from the ARTIA-Prostate trial:

Name of Structure	Dosimetric parameter	Per Protocol	Acceptable Deviation
Rectum	V36.25Gy (cc)	< 1 cc	≤ 2 cc
	V42Gy (cc)	< 0.03 cc	≤ 0.06 cc
	V34.43Gy (cc)	< 5 cc	≤ 7 cc
	D50% (Gy)	< 18 Gy	≤ 20 Gy
	D20% (Gy)	< 30 Gy	≤ 32 Gy
	D1.0cc (Gy)	< 36.25 Gy	≤ 38 Gy
Bowel_Small	V35Gy (cc)	< 0.03 cc*	≤ 0.1 cc
	V25Gy (cc)	< 5 cc*	≤ 7 cc
Bowel_Large	V35Gy (cc)	< 0.03 cc*	≤ 0.1 cc
	V25Gy (cc)	< 5 cc*	≤ 7 cc
Bladder	V36.25Gy (cc)	< 2 cc	≤ 10 cc
	V42Gy (cc)	< 0.03 cc	≤ 2 cc
	V32.62Gy (cc)	< 15 cc	≤ 20 cc
	D40% (Gy)	< 18 Gy	≤ 20 Gy
Urethra	V35Gy (cc)	< 0.1 cc	≤ 1 cc
Femur_Head_L	V19.9Gy (cc)	< 1 cc	≤ 3 cc
Femur_Head_R	V19.9Gy (cc)	< 1 cc	≤ 3 cc
Fiducials+Spacer**	DMax (Gy)	< 48 Gy	≤ 50 Gy
Fiducials**	DMax (Gy)	< 48 Gy	≤ 50 Gy
Ring_PTV_2cm	DMax (Gy)	< 48 Gy	≤ 50 Gy

*Bowel dose avoidance should be prioritized over other normal tissue avoidance. Bowel volume-dose criteria should be made as low as reasonably achievable without unacceptably violating other protocol parameters.

**Fiducial, Fiducial+Spacer, and Ring_PTV_2cm metrics are present to allow the contour to be visible in all online Ethos workspaces at the console.

Dosimetric Scorecard overview-points only:

Summary of 32 metric dosimetric 216 point scorecard, based on various clinical goal sets, guided this work.

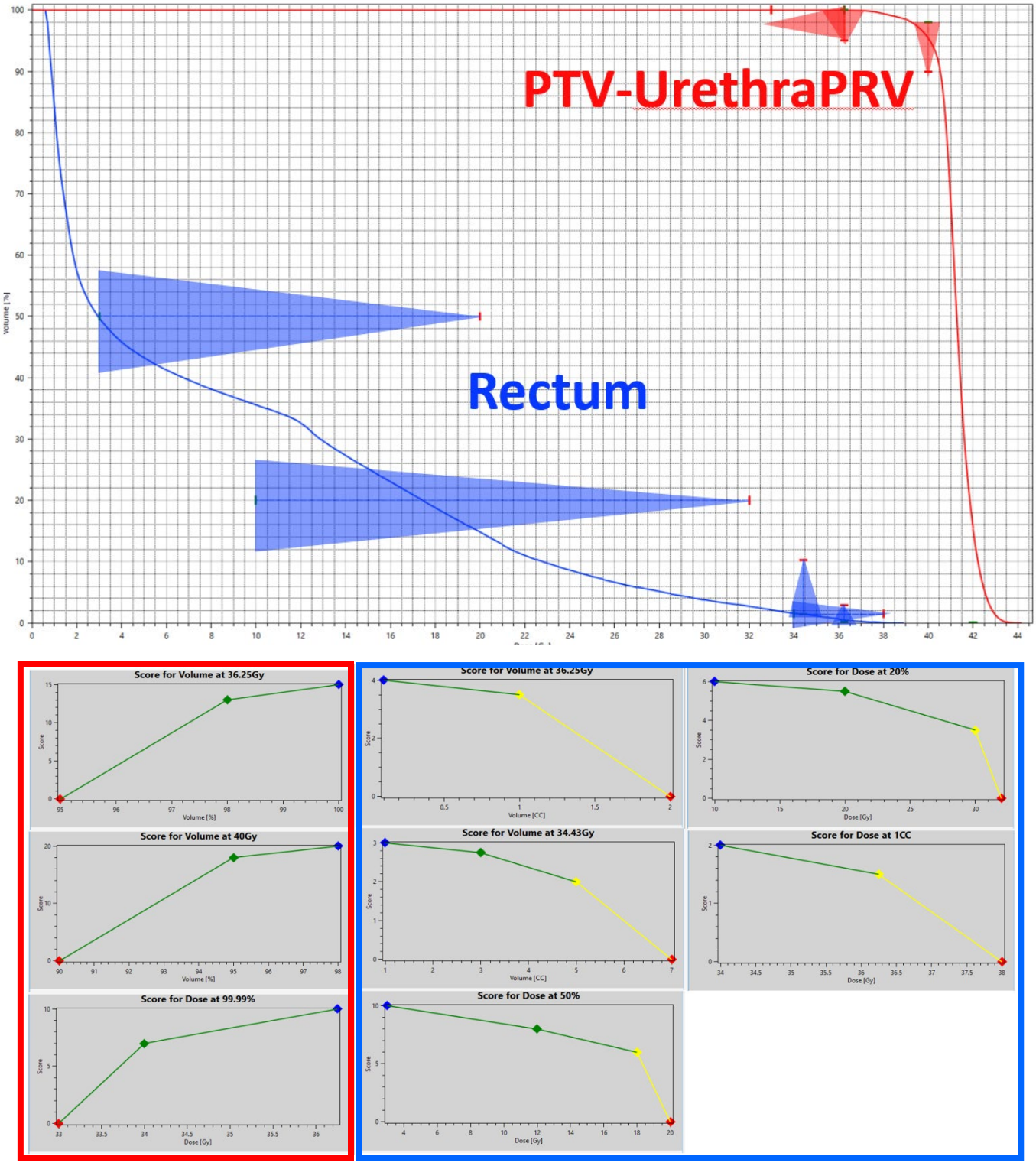
Metric Id	StructureId	Metric Text	Max Score
0	PTV	Volume at 40Gy [%]	2
1	PTV	Volume at 36.25Gy [%]	5
2	PTV	Dose at 0.1CC [Gy]	8
3	PTV-CTV	Dose at 0.1CC [Gy]	3
4	PTV-UrethraPRV	Volume at 36.25Gy [%]	15
5	PTV-UrethraPRV	Volume at 40Gy [%]	20
6	PTV-UrethraPRV	Dose at 99.99% [Gy]	10
7	PTV+Urethra	Dose at 99.99% [Gy]	5
8	PTV+Urethra	Volume at 30Gy [%]	10
9	CTV-UrethraPRV	Volume at 40Gy [%]	30
10	CTV-UrethraPRV	Dose at 99.99% [Gy]	12
11	Rectum	Volume at 36.25Gy [CC]	4
12	Rectum	Volume at 42Gy [CC]	3
13	Rectum	Volume at 34.43Gy [CC]	3
14	Rectum	Dose at 50% [Gy]	10
15	Rectum	Dose at 20% [Gy]	6
16	Rectum	Dose at 1CC [Gy]	2
17	Bowel_Small	Volume at 35Gy [CC]	6
18	Bowel_Small	Volume at 25Gy [CC]	4
19	Bowel_Large	Volume at 35Gy [CC]	3
20	Bowel_Large	Volume at 25Gy [CC]	2
21	Bladder	Volume at 36.25Gy [CC]	4
22	Bladder	Volume at 42Gy [CC]	4
23	Bladder	Volume at 32.62Gy [CC]	6
24	Bladder	Dose at 40% [Gy]	5
25	Urethra	Volume at 35Gy [CC]	6
26	Urethra	Dose at 0.1CC [Gy]	9
27	Femur_Heads	Volume at 19.9Gy [CC]	3
28	Fiducials	Dose at 0.03CC [Gy]	1
29	PTV Ring	Dose at 0.03CC [Gy]	5
30	50per Ring	Volume at 50% [%]	5
31	Body Ring	Dose at 0.03CC [Gy]	5

In general, how points are assigned between the various competing metrics on a dosimetric scorecard represents the physician's preference insofar as relative weighting, this weighting is a second order prioritization. Each function spans a DVH value range of two or more values (ranges not pictured, see next page), the starting, failing value (0 points) through the maximum, but often purposely unachievable, point value. The zero value represents a failure and is the first order priority. Optional intermediate point values can be added in between the failing point and the end of the aspirational range, covering the piecewise linear function shape and providing multiple levels of reasonably expected DVH values. Ideally, most maximum values are not achievable so as to continue to quantify additional improvement in already "very good" treatment plans. Care must be taken when attempting such a precise articulation of clinical intent. The full dosimetric scorecard provides a singular objective measure of dosimetric plan quality for a specific intent from which the RapidPlan optimization objective tuning can be manually iterated upon. This laborious model tuning process can prove worthwhile when such a RapidPlan model is deployed in a clinic and works as a single button press auto planning solution of high quality (as defined by it's associated dosimetric scorecard).

Example metrics for two structures are shown on the next page. For a full view of this dosimetric score card, see Annex B or download the scorecard json online here: https://medicalaffairs.varian.com/pelvis-prostateSBRT-vmat2

Dosimetric Scorecard selected piecewise linear metrics plotted on DVH:

Volume at Dose (vertical) and Dose at Volume (horizontal) lines *with expansions to represent increasing score*



Structure codes:

Recommended structure code assignment:

CTV-UrethraPRV	CTV_High(99VMS_STRUCTCODE)
PTV+Urethra	PTV_Low(99VMS_STRUCTCODE)
PTV-UrethraPRV	PTV_High(99VMS_STRUCTCODE)
PTV+Rectum	PTV_Low(99VMS_STRUCTCODE)
PTV-CTV	PTV_High(99VMS_STRUCTCODE)
PTV Ring	Ring(99VMS_STRUCTCODE)
50per Ring	Ring(99VMS_STRUCTCODE)
Body Ring	Ring(99VMS_STRUCTCODE)
Bladder	15900(FMA)
Bowel_Large	7201(FMA)
Bowel_Small	7200(FMA)
FemoralHead_L	55012(FMA)
FemoralHead_R	55011(FMA)
Fiducials	287890(RADLEX)
Rectum	14544(FMA)
Urethra	19667(FMA)

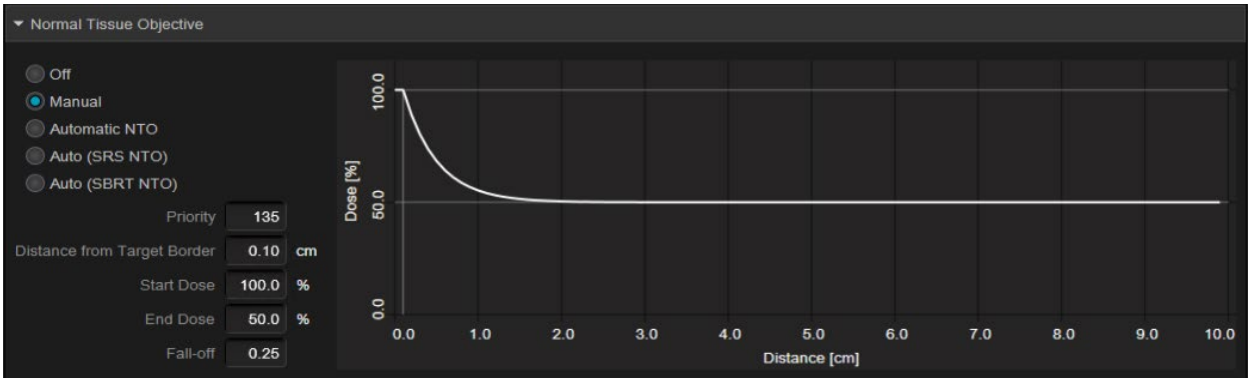
Example of matching the model to Plan structure ID's and entering target doses

Optimization objectives:

The following optimization objectives were defined in the model and will be generated when the model is applied to a new case:

ID		Vol [%]	Dose	Priority	gEUD a
CTV-UrethraPRV	(CTV_High)				
Lower		100.0	98.8 %	300	
Lower		98.5	102.0 %	400	
PTV+Rectum	(PTV_Low)				
Lower		100.0	100.0 %	175	
PTV+Urethra	(PTV_Low)				
Upper		0.0	104.5 %	300	
Lower		100.0	96.4 %	300	
PTV-UrethraPRV	(PTV_High)				
Upper		0.0	116.5 %	250	
Lower		100.0	107.6 %	325	
Lower		97.0	112.5 %	350	
50per Ring	(Ring)				
Upper		0.0	53.3 %	230	
Upper		1.0	45.1 %	170	
Upper (fixed vol., generated dose)		0.0	Generated	230	
Upper (fixed vol., generated dose)		1.0	Generated	170	
Bladder	(15900)				
Upper		0.1	90.0 %	120	
Upper		0.0	94.4 %	165	
Upper gEUD			88.0 %	130	35.0
Line (preferring target)		Generated	Generated	150	

ID		Vol [%]	Dose	Priority	gEUD a
Body Ring	(Ring)				
Upper		0.0	38.4 %	150	
Bowel_Large	(7201)				
Upper		0.0	92.5 %	150	
Bowel_Small	(7200)				
Upper		0.0	85.0 %	150	
FemoralHead_L	(55012)				
Upper (fixed vol., generated dose)		0.0	Generated	80	
Line (preferring target)		Generated	Generated	25	
FemoralHead_R	(55011)				
Upper (fixed vol., generated dose)		0.0	Generated	80	
Line (preferring target)		Generated	Generated	25	
Fidcials	(28789)				
Upper		0.0	102.5 %	200	
PTV Ring	(Ring)				
Upper		0.0	90.0 %	200	
PTV-CTV	(PTV_High)				
Upper		0.0	102.5 %	180	
Rectum	(14544)				
Upper		0.0	87.5 %	300	
Upper gEUD			78.0 %	120	35.0
Line (preferring target)		Generated	Generated	200	



Model Training:

ProstateSBRT-ARTIA was trained with a 41-case dataset from multiple institutions. 22 cases were from the ARTIA clinical trial with rectal spacers placed and 19 were used from other institutions without rectal spacers but with contouring performed following ARTIA guidelines (3mm PTV expansion). All cases included MR guided urethral contours. No clinical doses were used, only the clinical CTs and structures. All cases were manually replanned iteratively until a high score was achieved on the dosimetric scorecard. An initial, early model was created from those manually replanned cases. However, DVH prediction and one click performance of the initial model was not always achieving the highest scores on the dosimetric scorecard. Therefore, a final model was trained with the dose plans created by the initial model and optimization objectives were further tuned and refined. One such refinement was the creation of a PTV+Rectum overlap structure to reduce the hotspot on the overlap region (only used in cases where there is no rectal spacer). Ultimately, these adjustments were made to the model's objectives and optimization structures to enable increased flexibility for broad applicability of any SBRT prostate intent beyond the ARTIA protocol.

TRAINING SET SCORES			
Patient	**CTV CC's**	**Manual Replan**	**Initial Model**
1	111	198.54	199.26
2	58	198.89	200.15
3	51	190.82	190.08
4	75	196.50	199.84
5	68	195.19	198.44
6	89	193.65	198.61
7	60	200.51	201.10
8	62	187.91	188.49
9	78	184.20	186.01
10	32	178.95	186.61
11	83	194.26	195.79
12	80	197.25	201.08
13	59	195.86	196.08
14	52	190.95	192.86
15	79	195.02	194.62
16	73	186.86	187.26
17	47	194.37	195.71
18	33	196.08	194.89
19	44	188.38	193.09
20	78	170.03	179.48
21	63	193.04	196.75
22	36	191.39	191.90
RQ00291-3	117	182.09	182.24
RQ00305-1	51	188.82	191.02
RQ00312-0	59	177.80	190.03
RQ00313-1	96	177.02	173.54
RQ00319-6	17	182.23	182.69
RQ00332-8	37	173.02	174.70
RQ00340-7	42	173.36	173.68
RQ00348-2	32	184.26	183.51
RQ00365-2	68	165.60	170.19
RQ00369-9	76	171.17	179.76
RQ00386-2	62	190.10	190.88
RQ00421-0	59	183.24	184.58
RQ00445-6	68	185.25	186.59
RQ00451-6	41	170.45	171.93
RQ00463-5	59	180.71	185.22
RQ00464-2	56	169.82	176.74
RQ00466-1	56	174.88	179.68
RQ00541-7	42	179.79	176.85
RQ50141-5	50	173.70	173.49
Average	**60.95**	**185.41**	**187.69**

Model Validation:

10 additional cases were used for the validation of ProstateSBRT-ARTIA (5 ARTIA cases with rectal spacers placed and 5 previously treated patients not on the ARTIA trial from separate institutions, without rectal spacers). The five additional cases were contoured following the specifications of the ARTIA trial (3mm PTV expansion). The model was validated for different delivery platforms and optimization settings (See annex A).

Annex Directory

Annex A: **Validation Results**

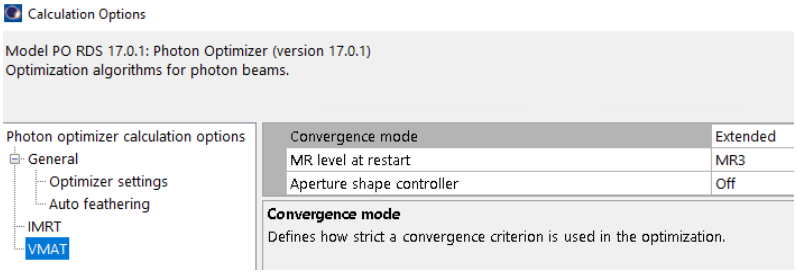
A1 Validation results for different delivery platforms Halcyon 6 Arcs, Halcyon/Ethos 19 Fields, and TrueBeam 3 Arcs for 10 validation cases.

Validation Results (216 points)			
Case	**Halcyon (6 Arcs)**	**Halcyon (19 Fields)**	**TrueBeam (3 Arcs)**
RQ00474-8	184.5	163.18	181.26
RQ00475-3	186.37	181.73	180.75
RQ00510-0	170.8	157.75	171.73
RQ00514-4	174.8	153.23	166.66
RQ00527-9	189.32	184.35	184.33
23	194.83	186.24	186.64
24	190.89	182.04	189.39
25	202.56	196.68	200.32
26	189.65	182.79	186.77
27	192.07	189.72	182.86
Average	**187.579**	**177.771**	**183.071**

A2: Convergence Mode: Off, On, Extended TrueBeam 6X-FFF v18 PO AXB MR3 Intermediate dose (v18 algorithms, adjusting convergence mode, MR3 return)

Case 26 validation with TrueBeam

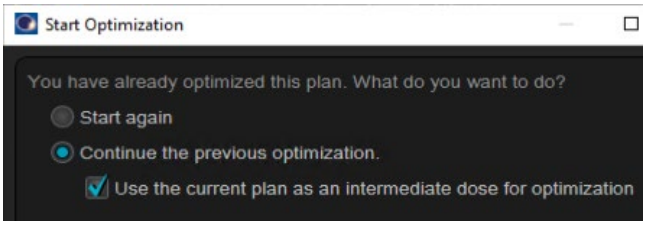
Use intermediate dose with MR3 return, adjusting convergence mode:



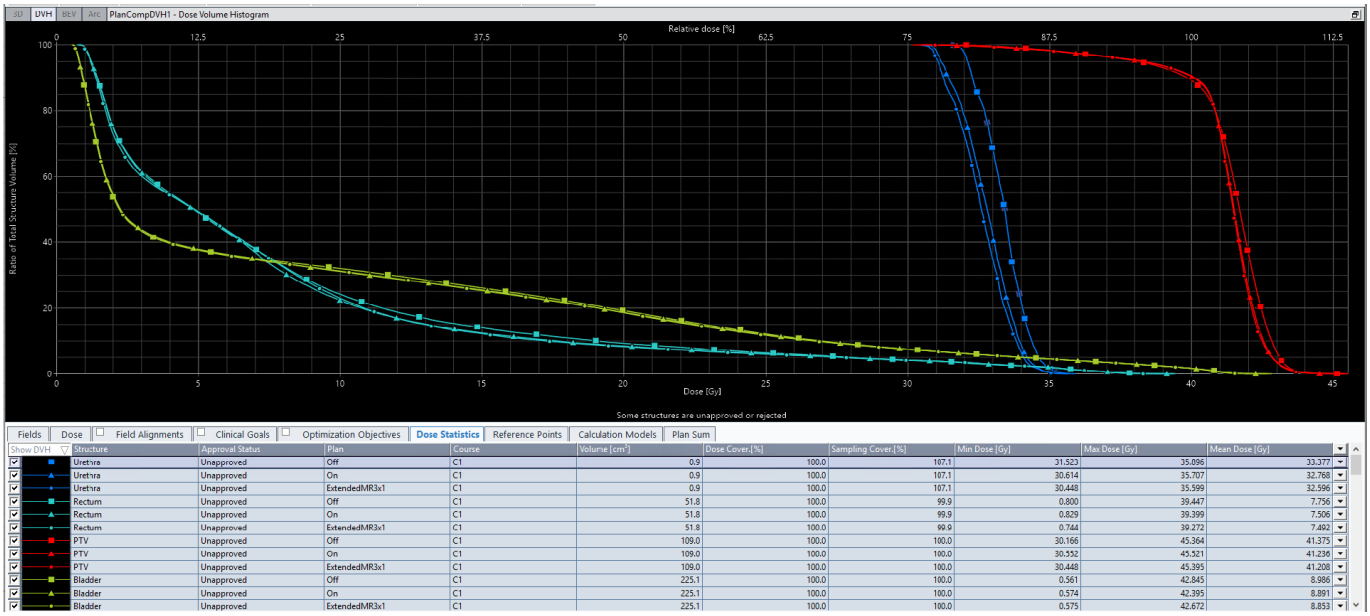
MR3x1= “Automatic Intermediate dose”

*GPU not required

MR3x2= multiple Intermediate dose optimizations, “current plan as an intermediate dose…“



4 Target 216 total 3 arcs Convergence Mode TrueBeam								
	TrueBeam v18(ELM) M120 with MR3 Intermediate							
	MR3 x1						MR3x2	
	Off		On		Extended		Extended	
Case	Score	MU	Score	MU	Score	MU	Score	MU
26	177.37	3630	186.66	4197	187.82	4548	188.48	4610



A3: HD-MLC vs M120 MLC comparison V17/V18

3 Target 216 total 3 arcs HDMLC vs M120 Truebeam 6X-FFF								
	TrueBeam							
	Opt. + Calc. Non ELM (V17)				Opt. + Calc. ELM (V18)			
	HD-MLC		M120		HD-MLC		M120	
Case	Score	MU	Score	MU	Score	MU	Score	MU
27	193.46	3847	188.28	4769	194.39	3686	183.42	4636

A4: MU and score results for V17 vs V18 PO for VMAT on Halcyon (Both with AXB V18)

Prostate SBRT								
Plan Scores/MUs (216 points)								
Plan #	v17 (MR3X1)	MUs	v17 (MR3X2)	MUs	v18 (MR3X1)	MUs	v18 (MR3X2)	MUs
1	197.19	5469.6	198.54	6118.4	193.02	4282.3	194.87	4493.9
2	182.89	5567.1	187.91	6155.7	180.08	5257	184.94	5745.3
3	173.33	5764.7	178.89	6267.7	169.13	5423.2	177.01	5876.9
4	192.59	5536.3	196.21	6248.4	191.57	4439	194.28	4767.1
Average	186.50	5584.43	190.39	6197.55	183.45	4850.38	187.78	5220.80

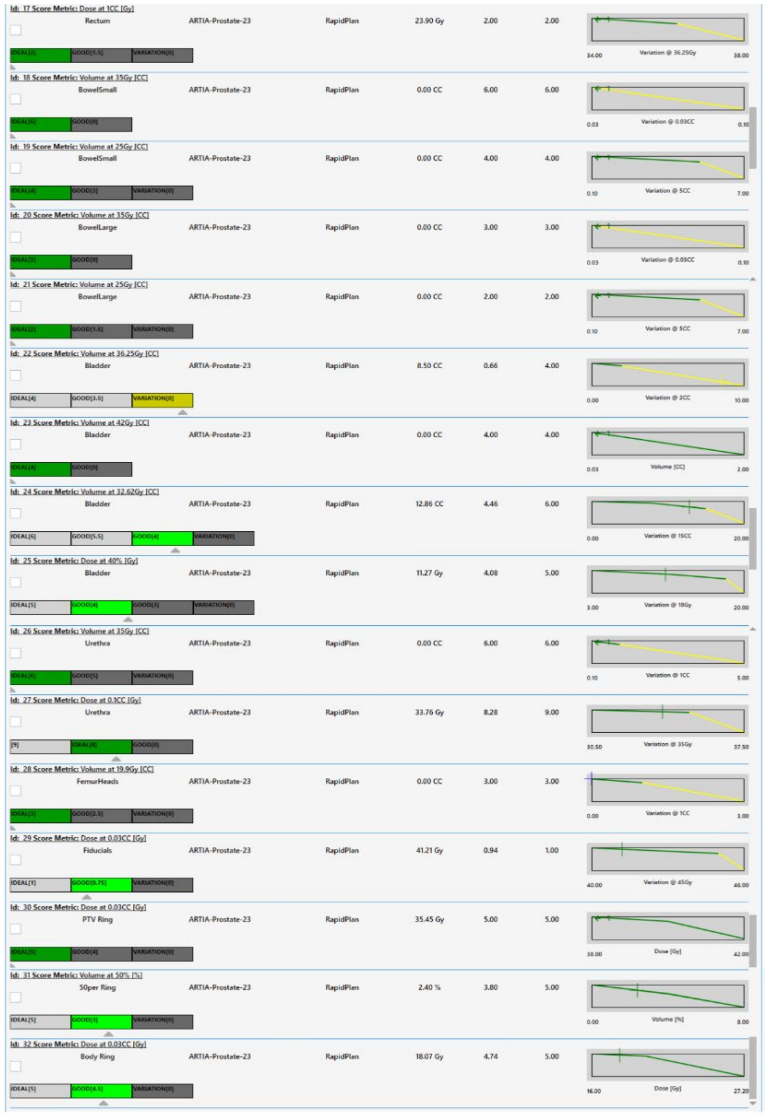
A5: Aperture shape controller for Halcyon and TrueBeam (V18 PO and AXB)

Apperature Shape Controller TrueBeam (216 Points)								
Case	Millenium 120 with MR3X2 Intermediate Dose							
	Off		Low		Moderate		High	
	Score	MU	Score	MU	Score	MU	Score	MU
24	192.17	4412.23	192.04	4322.15	192.5	4215.74	191.4	4184.33

Apperature Shape Controller Halcyon (216 Points)								
Case	SX2 with MR3X2 Intermediate Dose							
	Off		Low		Moderate		High	
	Score	MU	Score	MU	Score	MU	Score	MU
24	192.81	6409.33	193.09	6162.65	193.46	6009.3	193.22	6266.09

Annex B: Dosimetric scorecard details and PlansScoreCard ESAPI tool

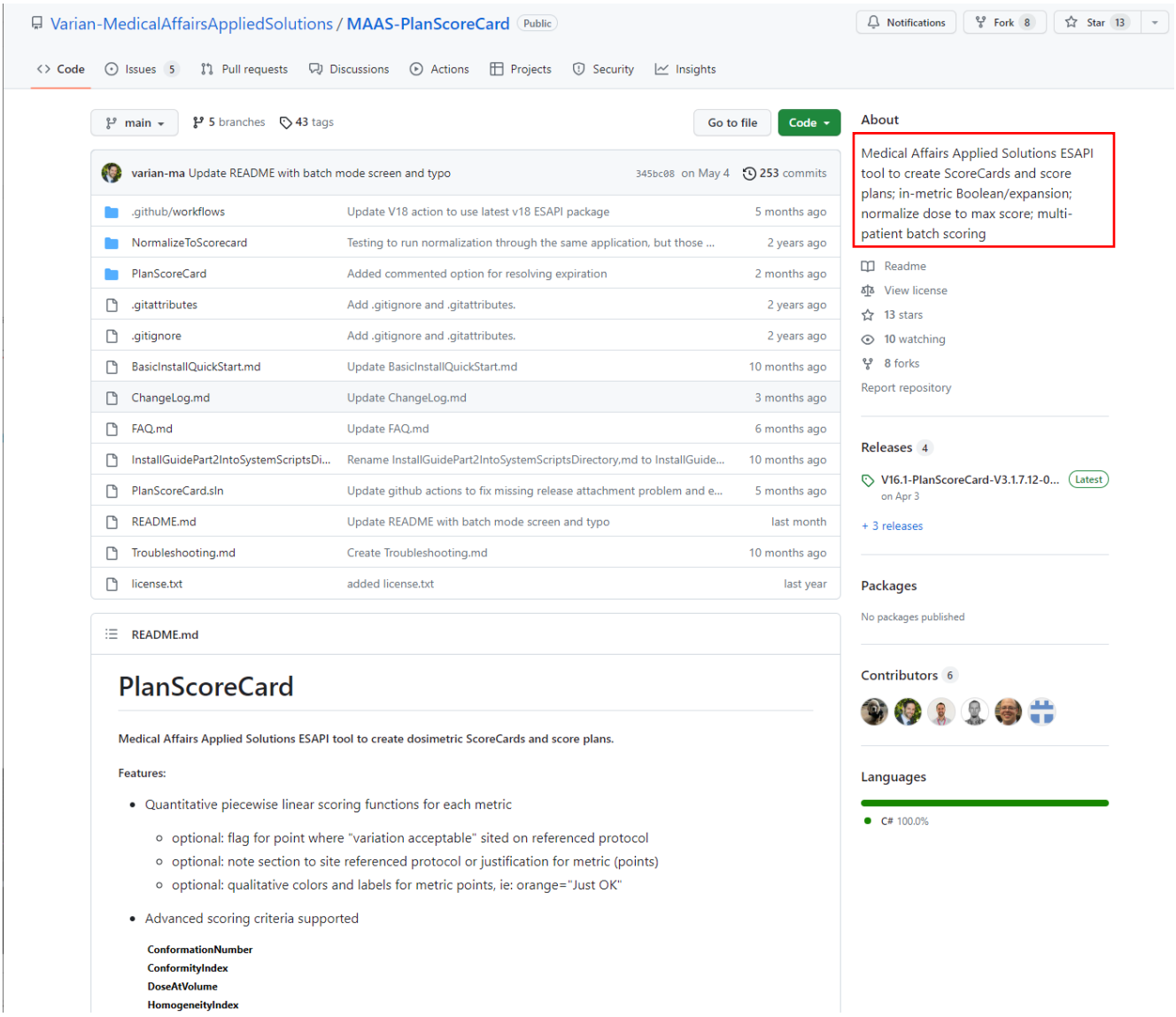
B1 Full Scorecard for Prostate SBRT 2 targets 216 point total



Download full Scorecard(json), DICOM case example and this RapidPlan model: https://medicalaffairs.varian.com/pelvis-prostateSBRT-vmat2.

B2 PlanScoreCard ESAPI tool: where to find

[Varian-MedicalAffairsAppliedSolutions](https://github.com/Varian-MedicalAffairsAppliedSolutions/MAAS-PlanScoreCard) (https://github.com/Varian-MedicalAffairsAppliedSolutions/MAAS-PlanScoreCard)



Currently, the source code is shared on the Varian Medical Affairs Applied Solutions GitHub where it can be downloaded and complied with Visual Studio 2022 (including with the free community edition), now in the releases section users can find precompiled binaries ready to run in all compatible versions of Eclipse (v15.6+). PlanScoreCard is made available under the Varian Limited Use Software License Agreement.

B3 PlanScoreCard ESAPI tool: automatically generate derived structures

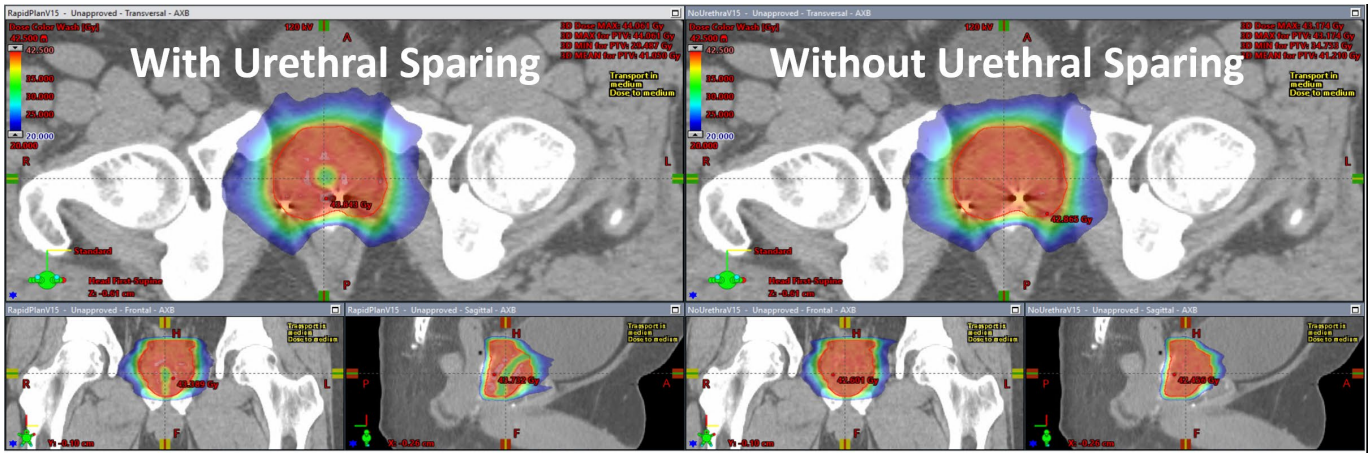
The PlanScoreCard tool has a feature where derived structures (made with Boolean and expansion tools) can be created automatically. These structures can be created temporarily (to be used for scoring the plan but never saved back to the database) or (if the ESAPI tool has been approved for writing) the PlanScoreCard tool's configuration file can be edited so these generated structures are saved.

Annex C: Optimization guide without urethral sparing (no urethra contour)

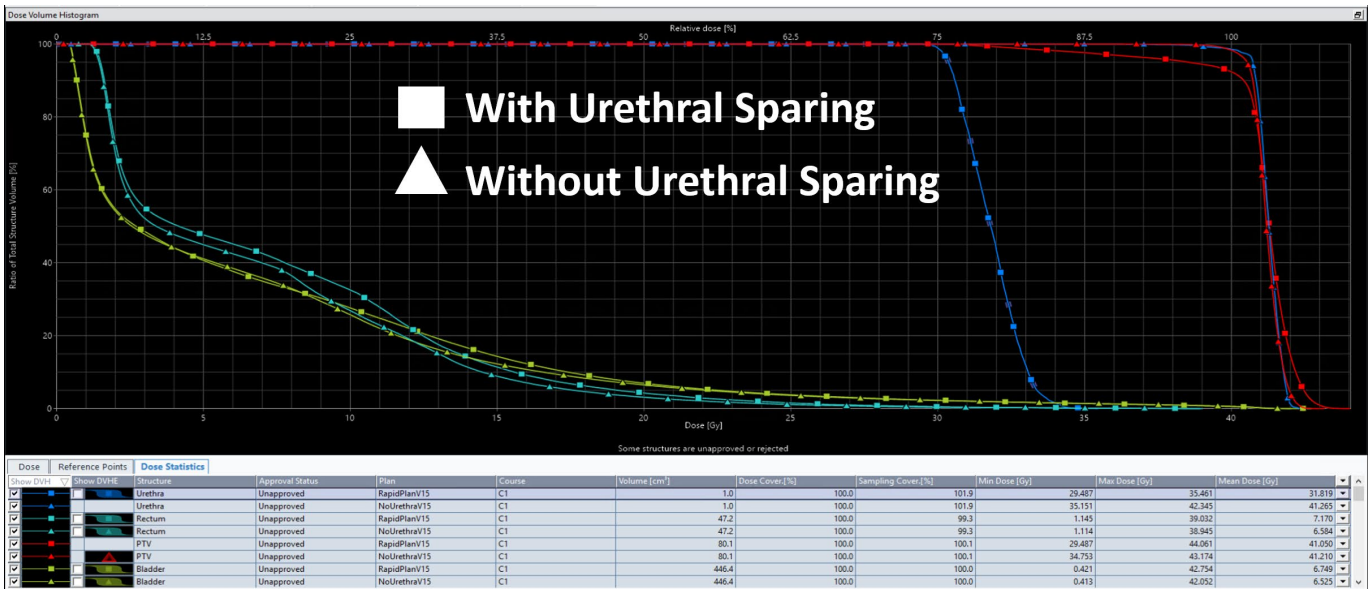
The following structure matching is recommended when the urethra contour is not present:

1. Omit the urethra and PTV+urethra (leave unmatched)
2. Match the structure set CTV to CTV-UrethraPRV
3. Match the structure set PTV to PTV-UrethraPRV
4. The PTV+Rectum can be optionally used (if PTV overlaps with rectum)

Matching structures to the model without urethra



Example isodose distribution with and without urethral sparing

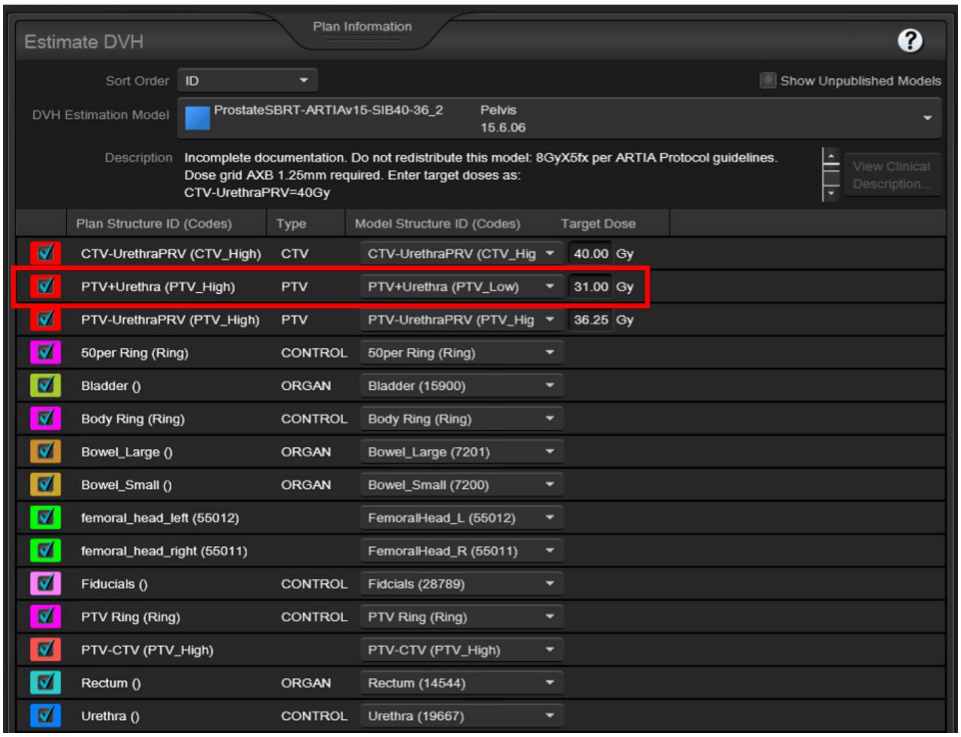


Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [Gy]	Max Dose [Gy]	Mean Dose [Gy]
Urethra	Unapproved	RapidPlanV15	C1	1.0	100.0	101.9	29.487	35.461	31.819
Urethra	Unapproved	NoUrethraV15	C1	1.0	100.0	101.9	35.151	42.345	41.265
Rectum	Unapproved	RapidPlanV15	C1	47.2	100.0	99.3	1.145	39.032	7.170
Rectum	Unapproved	NoUrethraV15	C1	47.2	100.0	99.3	1.114	38.945	6.584
PTV	Unapproved	RapidPlanV15	C1	80.1	100.0	100.1	28.487	44.061	41.050
PTV	Unapproved	NoUrethraV15	C1	80.1	100.0	100.1	34.753	43.174	41.210
Bladder	Unapproved	RapidPlanV15	C1	446.4	100.0	100.0	0.421	42.754	6.749
Bladder	Unapproved	NoUrethraV15	C1	446.4	100.0	100.0	0.413	42.052	6.525

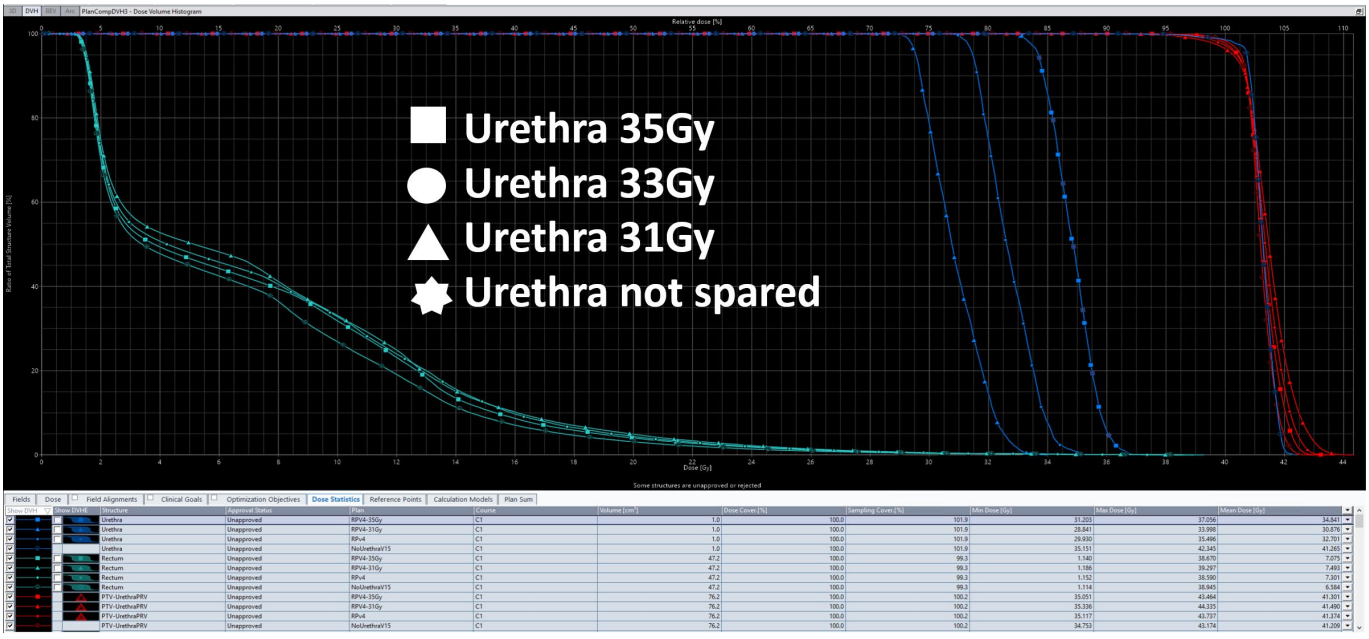
Example DVH with and without urethral sparing

Annex D: Urethral Dose Scaling

ProstateSBRT-ARTIA can optionally be used to scale the dose (either higher or lower) for the region where the PTV overlaps with the urethra. Do this by changing the target dose for the “PTV+Urethra” structure when applying the model as shown in the image below. Use caution when asking for urethral dose <33Gy as it will impact the amount of target heterogeneity and dose to OARs due to the steeper gradient for urethral sparing (See corresponding DVH of this annex section). **Scaling the urethra dose may not have the desired results if PTV+Urethra contains the entire PTV (Boolean = PTV OR Urethra). The ARTIA Ethos Clinical Directive Template (CDT) defines the structure as containing both (OR) not a union of the two structures (AND). See Annex E for applying this model to the ARTIA Ethos CDT version of this structure, with no urethral scaling functionality.**



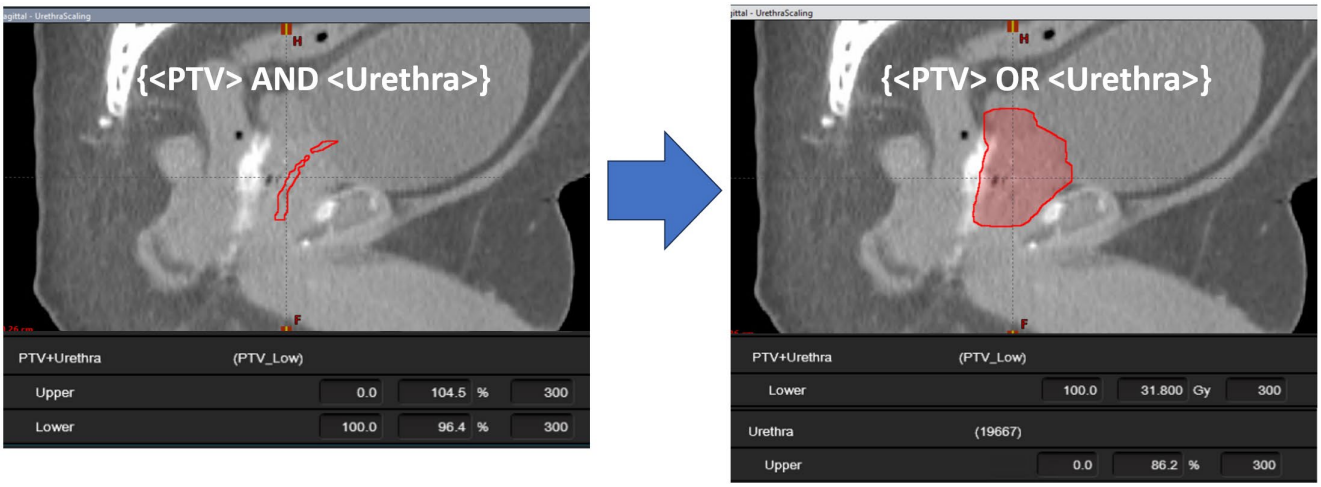
Example of changing the target dose for the PTV+Urethra to 31Gy.



Example DVH with four plans at different levels of desired dose to the Urethra: No sparing (40Gy), 35Gy, 33Gy, and 31Gy

Annex E: Editing the model for the PTV+Urethra ARTIA Ethos planning Template

This model recommends PTV+Urethra as a union of the two structures (AND). However, the ARTIA Ethos clinical directive template (CDT), generates PTV+Urethra as both (OR). However, the following edits need to be made in the model configuration workspace to this model's objectives if the PTV+Urethra includes the entire PTV (PTV OR Urethra), as generated by the ARTIA CDT. After making these changes, use the model as described in the rest of this clinical description, but without the ability to freely scale the urethral dose.



Annex F: Scaling the plan prescription dose

The model can be applied for different prescriptions. Using the following scaling factors for each target when generating the DVH estimates are recommended, although users can experiment with their own combinations.

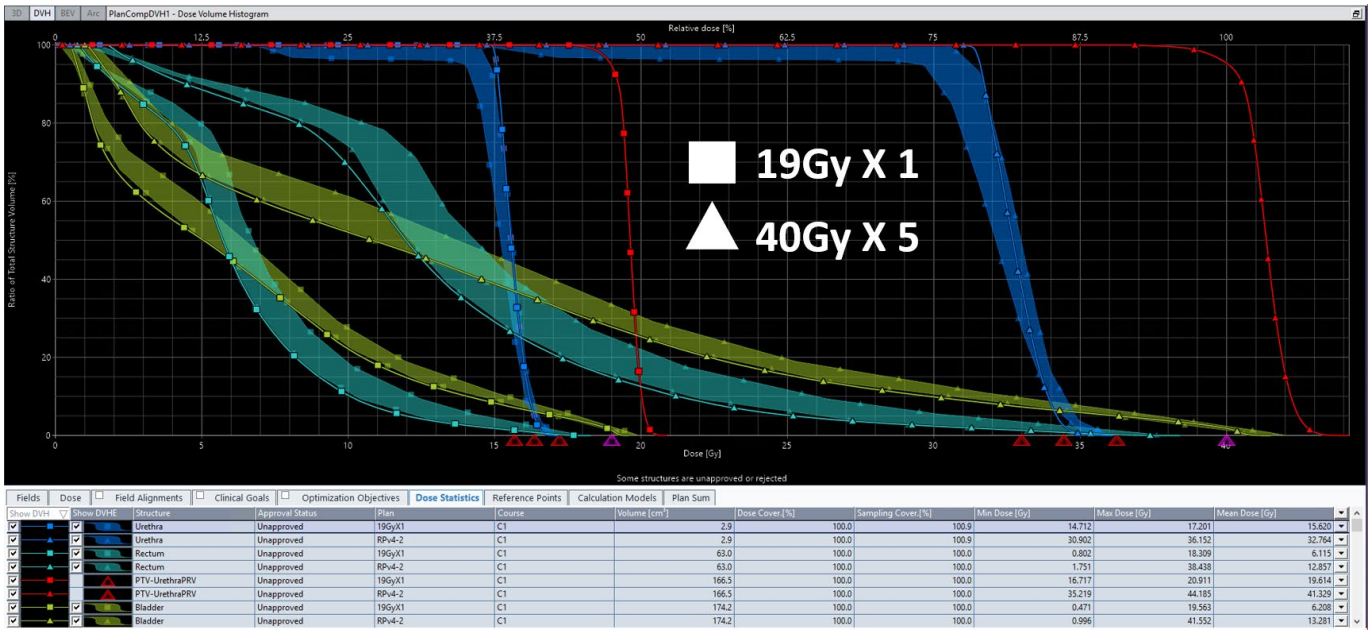
Target Name	**Scaling Factor**
CTV-UrethraPRV	100% of prescription (i.e. 40Gy)
PTV-UrethraPRV	90.6% of prescription (i.e. 36.25Gy)
PTV+Rectum	86.1% of prescription (i.e. 95% of 36.25Gy)
PTV+Urethra	82.5% of prescription (ARTIA value, see annex D)

Example of scaling the model for 19Gy in 1 fraction:

- CTV-UrethraPRV (19Gy X 1.0 = 19Gy)
- PTV-UrethraPRV (19Gy X 0.906 = 17.21Gy)
- PTV+Rectum (19Gy X 0.861 = 16.36Gy)
- PTV+Urethra (19Gy X 0.825 = 15.68Gy)

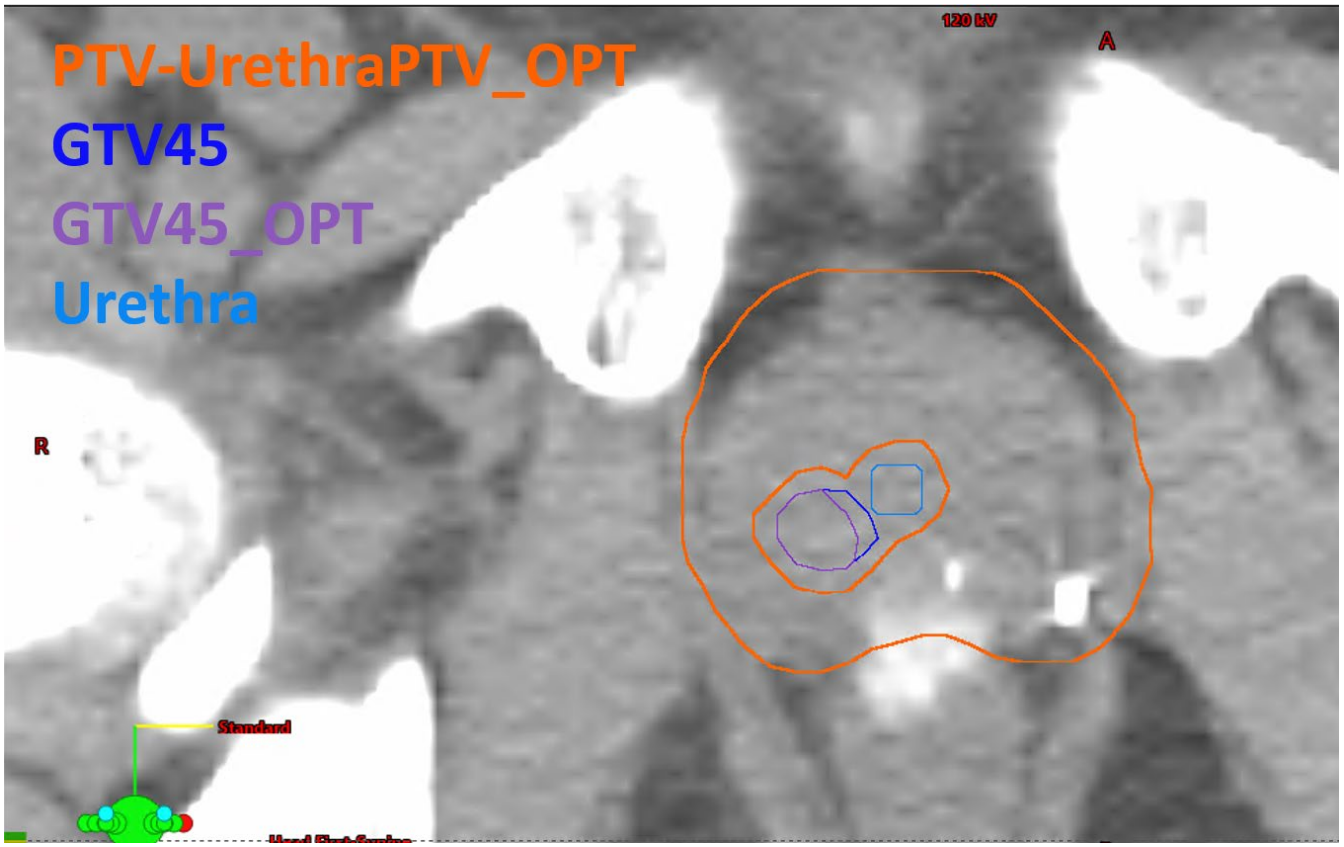
	Plan Structure ID (Codes)	Type	Model Structure ID (Codes)	Target Dose
☑	CTV-UrethraPRV ()	CTV	CTV-UrethraPRV (CTV_Hig	19.00 Gy
☑	PTV+Rectum (PTV_High)	PTV	PTV+Rectum (PTV_Low)	16.36 Gy
☑	PTV+Urethra (PTV_High)	PTV	PTV+Urethra (PTV_Low)	15.68 Gy
☑	PTV-UrethraPRV ()	PTV	PTV-UrethraPRV (PTV_Hig	17.21 Gy

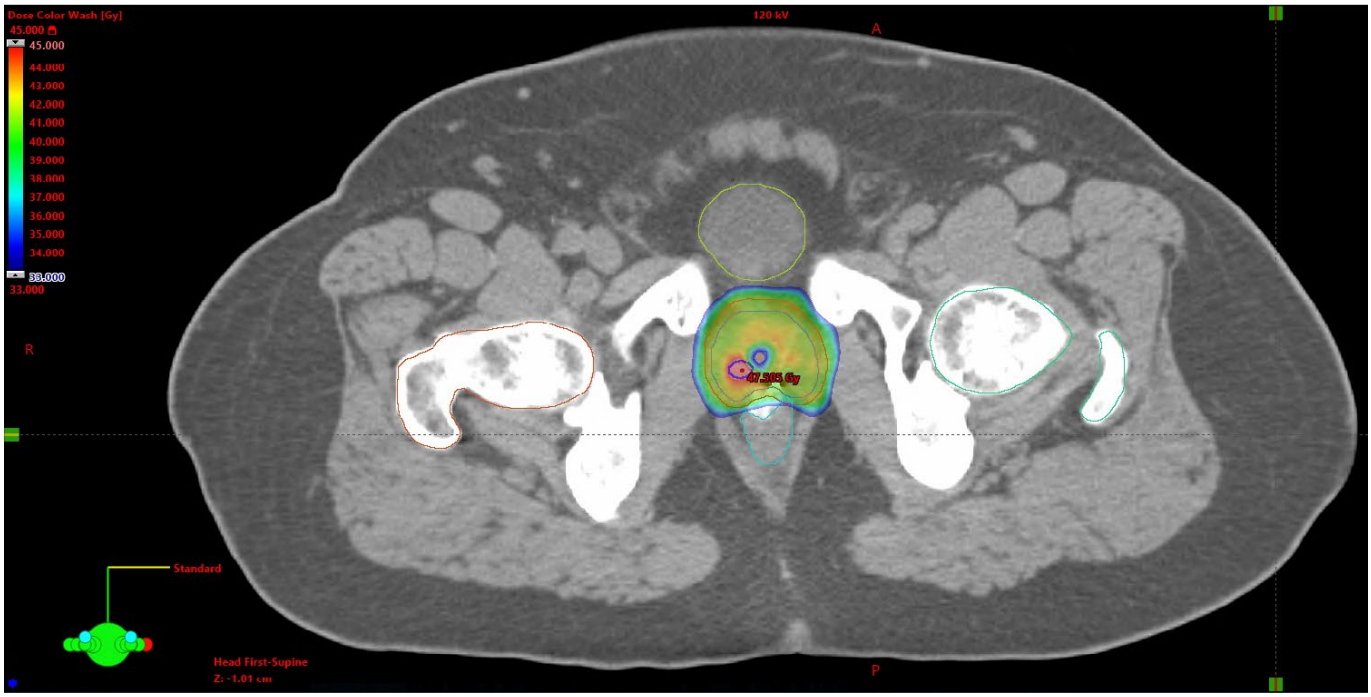
Jaccard M, Ehrbar S, Miralbell R, et al. Single-fraction prostate stereotactic body radiotherapy: Dose reconstruction with electromagnetic intrafraction motion tracking. Radiother Oncol. 2021;156:145-152. https://doi.org/10.1016/j.radonc.2020.12.013

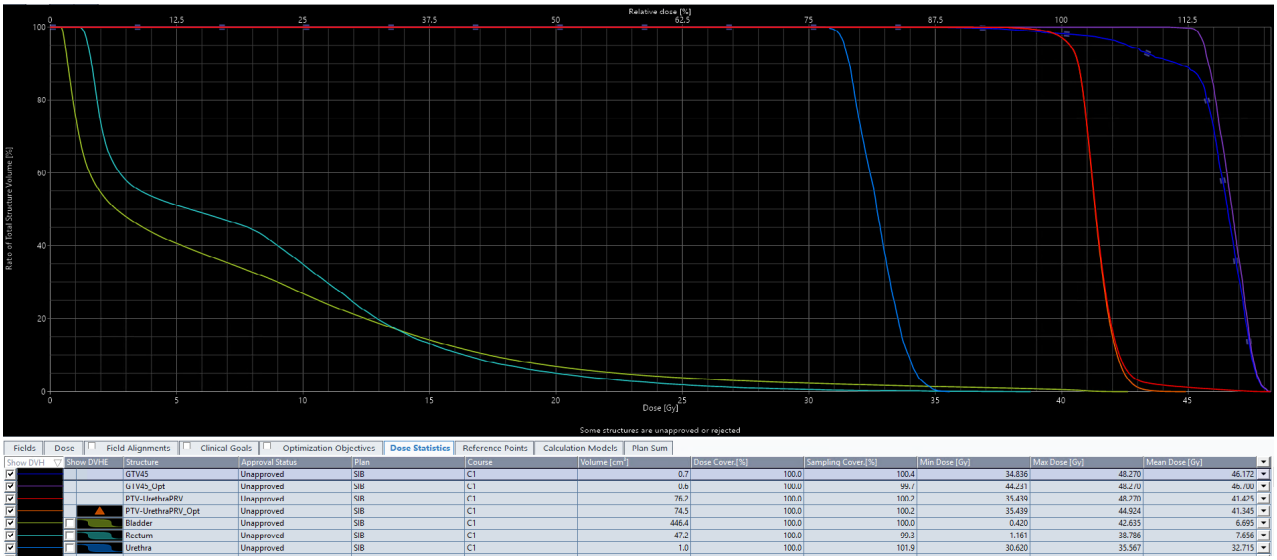


Annex G: Boosting gross disease volumes

Additional objectives for boosting the dose to gross disease volumes (I.e. GTV to 45Gy) can be manually added after applying the model. Use caution that new objectives do not conflict with those generated by the model and make manual adjustments to the values and priorities as needed. Proximity of the GTV to the urethra will be most impactful and is recommended to create a new GTV_OPT structure (GTV cropped +3mm from the Urethra) in these instances. A new PTV-UrethraPRV_OPT structure must be be created (PTV-UrethraPRV cropped +1mm from the GTV or GTV_OPT) and is matched to the target PTV-UrethraPRV when applying the model. This allows for the model to control dose heterogeneity in the PTV outside the region of overlap with the GTV. Increased distance when cropping optimization structures may be required when escalating the boost volume to greater than 45Gy. Example SIB optimization structures, dose distribution, and DVH are shown in the following images.

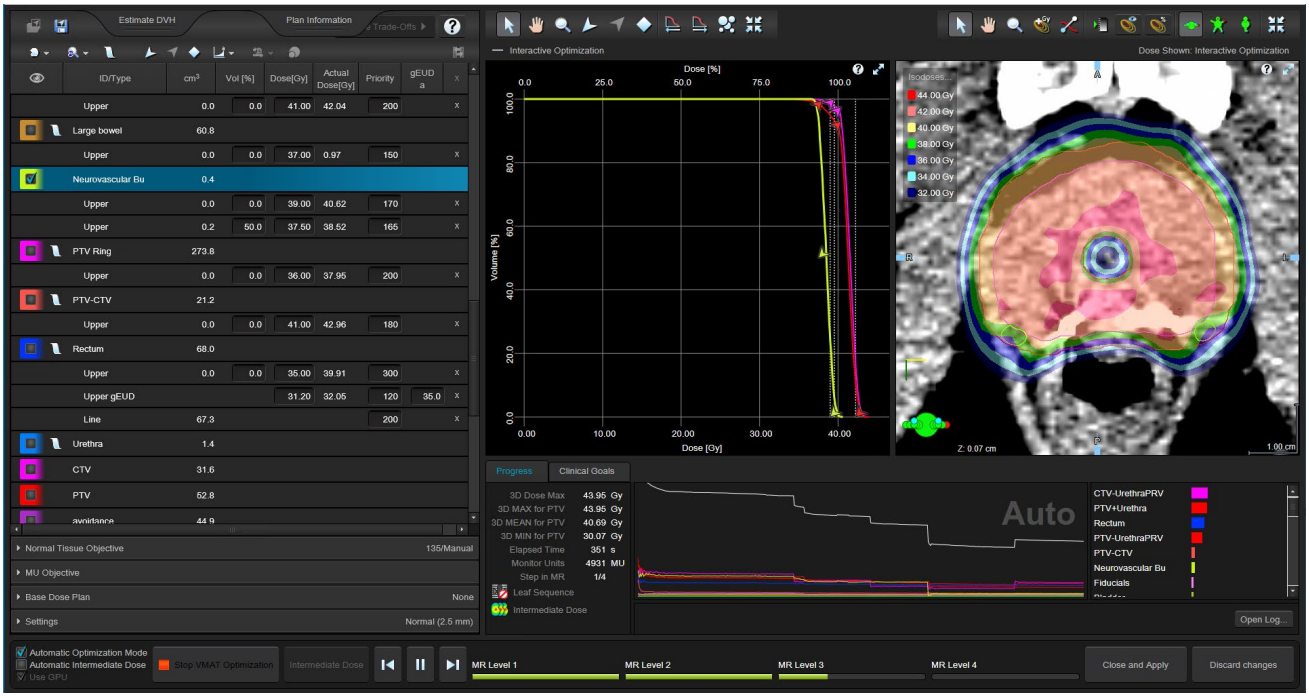

PTV-UrethraPTV_OPT
GTV45
GTV45_OPT
Urethra
120 kV
A
R
Standard


Dose Color Wash [Gy]
45.000
44.000
43.000
42.000
41.000
40.000
39.000
38.000
37.000
36.000
35.000
34.000
33.000
120 kV
A
R
Standard
Head First-Supine
P



Annex H: Including additional OARs

Additional objectives for OARs (I.e. neurovascular bundles D50% < 37.5Gy) can be manually added after applying the model. Use caution that new objectives do not conflict with those generated by the model and make manual adjustments to the values and priorities as needed. Example of adding optimization objectives to the neurovascular bundles while utilizing the model is shown in the image below.



Annex I: Acknowledgements

Manually optimized plans created by Lesley Rosa, CMD and Ryan Clark, MS CMD

All data generated and complied by Ryan Clark, MS CMD, Lesley Rosa, CMD and Anthony Magliari, MS CMD

Dosimetric Scorecard Prostate SBRT and derived structures designed by Anthony Magliari, MS CMD and Ryan Clark, MS CMD

Model generated validation plans created by Lesley Rosa, CMD and Ryan Clark, MS CMD

Clinical Description document created by Anthony Magliari, MS CMD and Ryan Clark, MS CMD

Annex J: Distribution and compatibility

This RapidPlan model is to be distributed exclusively via the links found on Varian Medical Affairs: https://medicalaffairs.varian.com/pelvis-prostateSBRT-vmat2

Please do not re-distribute this model as number of downloads will be tracked (strictly to judge the success of this project).

This RapidPlan model was built with Eclipse v18.0 and rebuild and validated from Eclipse v15.6 RapidPlan for maximal compatibility.